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Simulation trainer for practicing emergent open thoracotomy procedures

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ABSTRACT

Background: An emergent open thoracotomy (OT) is a high-risk, low-frequency procedure uniquely suited for simulation training. We developed a cost-effective Cardiothoracic (CT) Surgery trainer and assessed its potential for improving technical and interprofessional skills during an emergent simulated OT.
Materials and methods: We modified a commercially available mannequin torso with artificial tissue models to create a custom CT Surgery trainer. The trainer's feasibility for simulating emergent OT was tested using a multidisciplinary CT team in three consecutive *in situ* simulations. Five discretely observable milestones were identified as requisite steps in carrying out an emergent OT; namely (1) diagnosis and declaration of a code situation, (2) arrival of the code cart, (3) arrival of the thoracotomy tray, (4) initiation of the thoracotomy incision, and (5) defibrillation of a simulated heart. The time required for a team to achieve each discrete step was measured by an independent observer over the course of each OT simulation trial and compared.
Results: Over the course of the three OT simulation trials conducted in the coronary care unit, there was an average reduction of 29.5% ($P < 0.05$) in the times required to achieve the five critical milestones. The time required to complete the whole OT procedure improved by 7 min and 31 s from the initial to the final trial—an overall improvement of 40%.
Conclusions: In our preliminary evaluation, the CT Surgery trainer appears to be useful for improving team performance during a simulated emergent bedside OT in the coronary care unit.

1. Introduction

Chest reexploration via thoracotomy in the coronary care unit (CCU) for postoperative bleeding or tamponade is a rare but potentially life-threatening event [1–3]. Previous studies have approximated that 2%–6% of all patients undergoing cardiac operation require surgical reexploration in the early postoperative period [3–5]. Identification of cardiac tamponade in such patients can be difficult because it lacks the typical clinical and hemodynamic signs [6]. Sudden hemodynamic

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deterioration or cardiac arrest may be the first clinical indication, making the timing of thoracotomy critical to achieve a favorable outcome [7]. In a 6-y prospective audit of chest reopening after cardiac arrest, Mackay *et al.* [8] showed that 48% of patients opened within 10 min of arrest survived compared with 12% where time to reopening was delayed >10 min. Achieving this target requires an efficient, coordinated team effort between the CCU staff and the attending surgeon performing the procedure.

Cardiothoracic (CT) Surgery currently lacks a training model that specifically addresses the issues associated with emergency open thoracotomy (OT). This is a critical gap especially in light of challenges now facing residency training programs with reduced time for postgraduate training [9]. The current trend toward reduced hours in CT programs increases the urgency for residents and junior faculty to gain the requisite experience with the specialized and sophisticated maneuvers involved in performing an emergent OT.

New simulation training platforms will be required to enhance both technical and team skills training efficiency [10–14]. Leaders in the field of CT Surgery convened at the Visioning Simulation in Cardiothoracic Surgery Conference in April 2007 (Cambridge, MA) and identified team training in emergency situations and reentry thoracotomy as long-term simulation goals in adult cardiac surgery [15]. Furthermore, according to an international survey conducted by the European Association for Cardiothoracic Surgeons and the American Association for Thoracic Surgery, only 7% of respondents reported that they regularly practice for arrests, but 80% felt that specific training in this is important [16].

Although several simulation tools have been introduced to allow trainees to individually practice technical procedures such as beating-heart anastomosis, valvular replacement, and cannulation for cardiopulmonary bypass (CPB) [17,18], none address the need for entire teams of individuals to practice both the technical and team-based skills required during sudden, unexpected OT. With these goals in mind, we designed a novel CT Surgery trainer to practice and evaluate the feasibility of providing practice for OT in an *in situ* environment.

2. Methods

We modified a commercially available mannequin torso (Store Fixtures, Houston, TX) by incorporating both commercially available anatomic models and customized modules of artificial tissue to create a CT Surgery trainer. The trainer was designed for supine anterolateral thoracotomies, the standard approach for direct access to the heart in emergent thoracotomies in the CCU [19].

2.1. *Preparation of the torso*

Separate windows were cut into the left chest and right groin of the mannequin to permit the insertion of tissue modules. The thoracotomy window measured 18 × 7 cm and extended from just lateral to where the sternum would lie to the midaxillary line [19]. Replaceable femoral artery and venous access was created with a commercially available tissue module (Simulab Corporation, Seattle, WA) that was placed in the mannequin torso's groin to permit introduction of guide wires and shunts into both the femoral artery and vein for emergent CPB.

External access to the femoral line tissue module was established via latex tubing passed through side-ports drilled into the mannequin's right flank and permitted injection of suitably colored fluid to simulate arterial and venous blood. The addition of a pulsatile bulb allowed the operator to manually produce a realistic femoral pulse for appropriate arterial pressures.

2.1.1. *Anatomic models*

To provide anatomic landmarks for trainees during the OT, commercially available models of both the heart and lungs (Dapper Cadaver, Sun Valley, CA) were placed and firmly attached inside the chest cavity. This would allow for more realistic simulation of open cardiac defibrillation with paddle placement on opposite sides of the heart. Collapse of the left lung could also be affected with the lung model.

2.1.2. *Creating the chest wall*

A chest wall insert was created with platinum-cure silicone (Smooth-On, Inc, Macungie, PA), artificial blood (ICU Blood Products Cosmetic), and plastic rib bones (3B Scientific Corporation, Tucker, GA).

An outer skin layer was created first using a 2-component soft platinum-cure pigmented silicone rubber layer (Dragon Skin FX-Pro; Smooth-On, Inc). On top of that bottom layer, 6-inch-long tubing (1/16 in internal diameter) was placed to provide plumbing for simulating arterial vessels. A small blood pocket was then created with a thin (10 × 15 cm) piece of silicone; this served as a reservoir for artificial blood to flow realistically during the skin incision. An external pressurized reservoir was then attached to the buried silicone tubing to permit realistic arterial bleeding during the simulated thoracotomy. Plastic rib bones were placed to simulate thoracotomy access in the fifth intercostal space. Ribs were sufficiently long to permit placement of chest wall retractors (Fig. 1).

Fig. 1 – Thoracotomy retractors in place. Ports depicted for modification of the model for robotic procedures. (Color version of figure is available online.)